Artificial Ear- A Wearable Device for the Hearing Impaired

Pavlidou, A., Lo, B.
Imperial College London, United Kingdom

HAMLYN SYMPOSIUM ON MEDICAL ROBOTICS 2021

Introduction

- This work aims to introduce the design of a non-invasive hearing aid device, for patients suffering from inner-ear damage.
- Designed to convert the incoming speech signal into tactile signals
- Output applied behind the subjects' ears using vibration motors.
- Utilizes somatosensory system rather than hearing system and thus should work regardless of the reason for the impairment

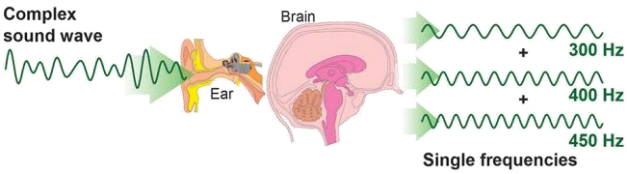

Figure 1 - *How the brain perceives complex sound signal [1]*

Facts about hearing loss

- 11 million people in the UK suffer from hearing loss. [2]
- Current available technology will benefit 6.7 million of them.[2]

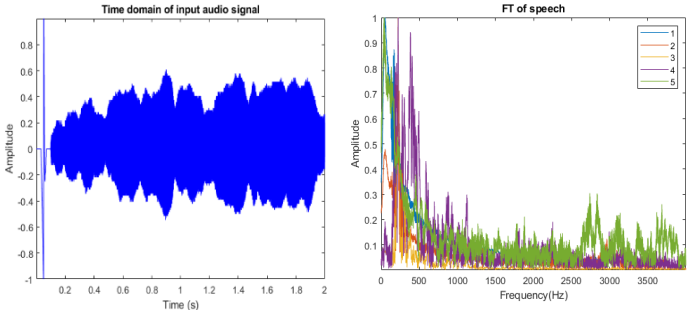

Figure 2 - Audio signal in time and frequency domain

Results

Performing FT to phonemes

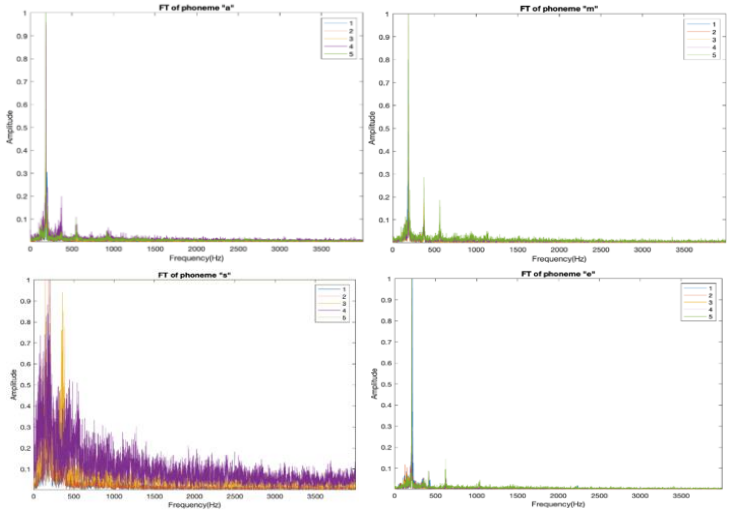

Figure 4 - Frequency domain of multiple recordings of phonemes 'a', 'm', 's', and 'e' overlapped to indicate correlation of overtones.

Testing the vibration patterns

- Subjects able to guess the letters, with some prior training

Aim 1 - Understand how speech signals are formed
- Divide speech signal into individual phonemes
- Perform Fourier Transformation
- Collect characteristics of different phonemes in the Frequency Domain

Aim 2 - Convert speech into tactile feedback
- Assign a vibration pattern to each phoneme
- Apply them behind the subject's ears

Aim 3 - Accurately recognise each phoneme based on the speech signal
- Create Algorithm to classify the phonemes (current task)

Method

Input- Capturing and Processing the Audio Signal

- Recorded in casual speaking pitch using MATLAB (Fig. 4)
- Visualized in frequency domain to observe the differences between the position of the harmonics

Output- Motors

- 3 DC motors ($2^3 = 8$ possible patterns)
- Words spelled out on the back of the subject's hand using the patterns corresponding to the letters (Table 1)

Classification Algorithm

- The phoneme recognition algorithm will be based on the difference between the component frequencies

Table 1- Respective patterns for letters

	PATTERN	LETTER
1	000	''
2	001	'H'
3	010	'E'
4	011	'L'
5	100	'O'
6	101	'W
7	110	'R'
8	111	'D'

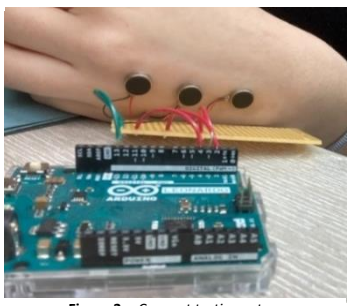

Figure 3 - *Concept testing set up*

Discussion

- FT of individual phonemes indicate that the distance between harmonics is unique between them (for the same reason that everyone's voice is unique and musical instruments sound differently)[3,4]
- Vowels tend to be simpler than most consonants hence some consonants may require more complex processing [3,4,5].
- 44 phonemes found in the English vocabulary will require 6 motors. [6]

Future plan

- Move project to Raspberry Pi to make compact
- Make processing time as short as possible to allow for real time operation
- Finish Classification Algorithm

References

[1] Pasco.com. 2021. *Sound Waves*. [online] Available at: <https://www.pasco.com/products/guides/sound-waves#:~:text=Sound%20is%20produced%20when%20an%20object%20vibrates%2C%20creating%20a%20pressure,solid)%20to%20have%20vibrational%20motion.&text=The%20human%20ear%20detects%20sound,small%20parts%20within%20the%20ear.> [Accessed 6 March 2021].**[2]**"Facts about deafness & hearing loss - Hearing Link", *Hearing Link*, 2021. [Online]. Available: https://www.hearinglink.org/your-hearing/about-hearing/facts-about-deafness-hearing-loss/. **[3]** A. Benade, Fundamentals of Musical Acoustics. Newburyport: Dover Publications, 2012, Chapter 19 **[4]** J. Sundberg, "The Acoustics of the Singing Voice", Scientific American, vol. 236, no. 3, pp. 82-91, 1977 **[5]** "Harmonics Vs. Formants", *VoiceScienceWorks*. [Online]. Available: https://www.voicescienceworks.org/harmonics-vs-formants.html. **[6]** English, 4., 2021. *The 44 Phonemes in English*. [online] Dyslexia Reading Well. Available at: <https://www.dyslexia-reading-well.com/44-phonemes-in-english.html> [Accessed 11 June 2021].